# OPTION 1F
# LIGHT-DUTY DIESEL VEHICLES

## Description

This option examines greater use of light-duty diesel (LDD) vehicles (less than 8,500 pounds gross vehicle weight) to address California's growing transportation energy demand. LDD's market penetration, impacts on refinery balance, and overall impacts on fuel prices are evaluated through 2025. This option considers an "Aggressive Case" scenario, which assumes 12 percent LDD penetration for cars and 21 percent penetration for trucks.

The Energy Commission forecasts that by 2025, 60 percent of growth in on-road transportation fuels will be for gasoline.[1] In the Aggressive Case Scenario, all growth in on-road transportation fuel demand is met with increased diesel fuel use via light-duty dieselization.

## Background

### *Engine Technology and Market Response*

Turbo-charged, direct-injection, LDD engines are a well-established technology that captured 48 percent of the European passenger car market in the 2004 model year.[2] While higher fuel prices in Europe are part of the explanation for this, it appears that European car buyers consider the modern diesel an acceptable alternative to the gasoline engine vehicle, despite their higher price. Diesels offer attributes beyond fuel economy and cost that will affect their use in California's market. Greater driving range and durability, and higher torque (better response) compared to gasoline counterparts may allow the diesel to capture a larger share of the California market.[3]

### *Fuel Supply*

California refiners maximize production of gasoline from crude oil relative to diesel and jet fuel. In 2000, gasoline represented 64 percent of each barrel of crude oil produced with jet fuel at 18 percent and diesel at 12 percent.[4] Although greatly influenced by the refineries' complexity and crude oil composition; the maximum yield of refined products, at the lowest cost, is with less gasoline, and more diesel production. Staff assumes that applying an Energy Information Administration (EIA) analysis findings to California's market, moving towards a lower-gasoline and higher-diesel production, would greatly improve California's market resilience and lower prices.[5] Increasing LDD vehicle penetration as a means to help balance demand is crucial to achieving this result.

### *Air Quality Concerns*

Historically, diesel engines emitted significantly more exhaust emissions of oxides of nitrogen ($NO_x$) and particulate matter (PM) than their gasoline counterparts. Conversely, diesel engines emitted lower hydrocarbons, carbon monoxide, $CO_2$, and essentially no evaporative emissions. In 1998, California Health and Regulatory Agencies concluded that diesel exhaust is a toxic air contaminant. In 2004-2010 federal and state exhaust emission or air quality regulations standards compel both gasoline and diesel exhaust emissions to be reduced to near-zero levels for all regulated exhaust emissions including PM.

All LDDs offered in California beginning in 2008 will use PM aftertreatment devices which reduce PM by at least 95 percent.

Particulate emissions emitted by on-road diesel-fueled vehicles are expected to decline by 60 percent from 1995 to 2010 as a result of mobile source air quality regulations already adopted by the California Air Resources Board (CARB).[6]

The U.S. Environmental Protection Agency (EPA) has noted the positive progress of the emissions performance made with diesel engines and diesel emission controls.[7] The EPA claims that once diesel engines attain the adopted standards, they will be as clean as gasoline engines for heavy and light-duty applications. Furthermore, the potential health risks associated with diesel exhaust are reduced to the equivalent gasoline level by the federal Tier II Emissions Standards.[8, 9]

## Status

Until September 1, 2006, when 15 parts per million (ppm) sulfur diesel fuel is available nationwide, vehicle manufacturers are precluded from selling federal Tier II Bin-5 or California equivalent low-emission vehicle (LEV) II compliant diesel vehicles. (For brevity sake, this paper will use the federal Bin-5 exhaust emission standards to also include the CARB LEV II standard, even though there are compliance differences between the two standards.)

Although, no LDD vehicle has been certified to the federal Bin-5 exhaust emission standards, the EPA has tested five vehicles that meet these standards at low mileages.[10, 11] In 2004, Cummins demonstrated under more difficult conditions than specified for the federal Bin-5 standard, a diesel engine meeting federal Bin-5's useful life emission levels. As of early 2005, compliance with EPA's and CARB's $NO_x$ emission standards is still viewed by the automotive industry as the greatest impediment and risk to the widespread market penetration of LDDs in the U.S. and California markets.

Meeting the exhaust emission standard for $NO_x$ remains a critical challenge, both technically and economically, for diesel technology. One manufacturer has demonstrated a federal Bin-5 compliant diesel engine; however, the emission compliant power train costs more than the industry believes they can recover in the market. Further refinement is necessary to develop a lower-cost emission compliant diesel engine. Yet, even with significantly greater success, the final LDD vehicle at the Bin-5 (and lower) levels may still prove too great a risk and challenge for industry to take.

LDD vehicles make up less than two percent of California's LDD population. Sales of LDD vehicles ceased in the 2004 model-year because California's gasoline-based exhaust emission standards cannot be met with California's high sulfur diesel fuel. Meanwhile, diesel-fueled pick-up trucks certified to diesel-based emission standards (gross vehicle weight of 8,501 – 10,000 pounds) have reached over 52 percent of 2003 model-year registered vehicles.[12] Diesel-powered, heavy-duty suspension, sport utility vehicles (SUVs) of this size, first offered in 2000 in California, represented 27 percent of their vehicle class in 2003. Excluding heavy-duty vehicles (over 10,001 pounds), California's gasoline vehicle population is near 24.5 million, and about 350,000 vehicles are registered as diesel-fueled.

## Assumptions

The information presented below was adapted from an assessment performed by K.G. Duleep[13] and Energy Commission staff. The assumed projected incremental retail price for 2008 and beyond 2012 LDD vehicle sizes is presented in Table 1. The LDD vehicles referenced in Table 1 are targeted to meet federal Bin-5 emission standards. Energy Commission staff determined fuel economy improvement values as shown below.

### Table 1. Diesel Vehicles Incremental Prices and Fuel Economy Used

| Vehicle Size | Diesel Vehicles Incremental Retail Price, $ | Volumetric Fuel Economy Multiplier Compared to Gasoline [a] |
|---|---|---|
| Small Car | 2,350 | 1.35 |
| Large Car[b] | 3,150 | 1.35 |
| Sport Utility Vehicle | 3,150 | 1.40 |
| Minivan | 3,150 | 1.40 |
| Pickup Trucks, Large Vans | 3,400 | 1.45 |

[a] The fuel economy improvement of the diesel vehicle includes the impact of complying with California's LEV II (federal Bin-5) emission standards.
[b] The large car size includes intermediate-sized cars

From the data gathered on production vehicles in North America and Europe, the range of fuel economy improvement for an LDD, expressed as a fuel economy multiplier, is 1.20 to 1.65 with a mean of 1.40 to 1.45 city to highway, respectively. Staff assumed that the average LDD vehicle will have a fuel economy improvement range within these values. Staff used a 1.45 fuel economy improvement multiplier for full-sized SUVs, vans, and pickup trucks; 1.40 for mini-vans, smaller SUVs, and compact pickup trucks; and 1.35 for large and small cars.

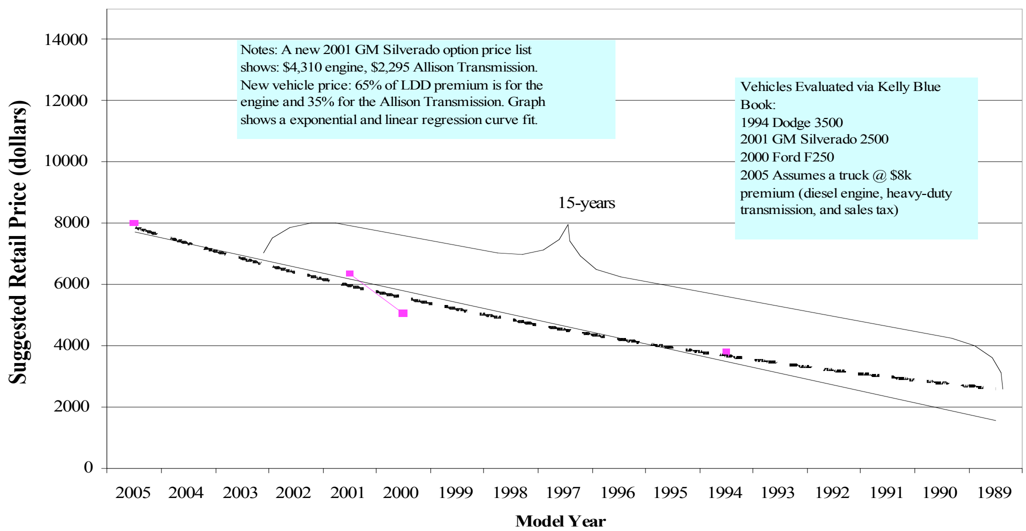
The base case for LDD market penetration was determined by employing the CALCARS model, using the vehicle classes with the attributes shown in Table 1. The CALCARS model was run assuming the concurrent availability of gasoline-hybrid vehicles competing in the same market. The incremental vehicle price used in this analysis assumed additional cost for federal Bin-5 emissions compliance. The base case is adopted as part of the Energy Commission's base demand forecast and is discussed in the *Forecasts of California Transportation Energy Demand 2005- 2025.*[14]

Staff assumed that manufacturers introduce LDDs complying with California's LEV II emission standards into California's market in 2008. This assumes that NOx and PM after-treatment will be available and used on LDD vehicles in 2007 and subsequent model years, allowing sales to occur. LDD vehicles are assumed to emit at the same particulate levels as gasoline vehicles. Staff also assumed that ultra-low sulfur diesel fuel (15-ppm sulfur) will be available in mid-2006, as required by the EPA and CARB regulations.

Staff also assumed diesel retail station availability to be 33 percent for the initial years, growing to 50 percent by 2020. This was based in part on the Oak Ridge National Laboratory's (ORNL's) analysis[15] and a 1998-1999 survey of approximately 7,500 retail service stations in California.[16] The existing retail infrastructure for dispensing diesel is assumed adequate for the projected growth in diesel vehicle population during the initial years for the scenario evaluated. For additional infrastructure beyond this level, staff assumed that the cost of expanding retail fuel stations to dispense diesel will be absorbed by private industry as a normal investment option, controlled by the economic opportunity of supplying diesel fuel to meet demand. The diesel fuel price used in the analysis includes a retail margin that would normally pay for infrastructure expenses.

The operating cost of LDD vehicles is assumed to be the same as their gasoline counterpart, excluding fuel and depreciation cost. This assumes that the net cost of oil changes, tune-ups, maintenance, insurance, and smog inspections are roughly equivalent. According to Kelly Blue Book values, diesel vehicles depreciate at a slower rate than their gasoline counterparts. Figure 3 shows suggested sales price differentials for some used diesel pickup trucks compared to gasoline vehicles. Staff conservatively determined LDDs retain 25 percent of the incremental purchase price of the diesel option after 15-years of service. Consequently, a $2,350 incremental price for a new diesel engine, after 15 years, would have a present value of $95 and $250 respectively assuming a 12 and 5 percent discount.

Fig. 3 **Kelly Blue Book Differential Retail Prices of Used Pickup Trucks**




# Aggressive Case

Theoretically, among various options, California's future transportation fuel demand can be met by significantly expanding either gasoline or diesel production. The Aggressive Case Scenario considers the impacts of meeting California's future transportation energy demand with diesel and evaluates its impacts and economics.

Currently, 64 percent of crude oil is refined into gasoline, 12 percent into diesel and 18 percent into jet fuel in California. These proportions result from market demands and are assumed to reflect the lowest production cost for these fuels and related volumes. However, future demand could be influenced to produce a refinery product distribution that uses crude oil more efficiently and with greater product volume per unit crude oil processed. We expect that a more efficient refinery would produce less gasoline, more diesel and jet fuel if market conditions were suitable for this output distribution.[17] Staff designed the Aggressive Case with the objective to cap gasoline demand at current levels, and to use LDDs to meet future demand growth. Staff relied upon a 1998 analysis performed by the EIA to quantify the affects and benefits.[18]

Staff applied the EIA analysis for a 30 percent light-duty diesel penetration, (modeled nationally, but applied to the California market) to further evaluate this scenario. Accordingly, a 30 percent LDDs penetration would result in a 22 percent reduction in gasoline demand and a 52 percent increase in diesel use for 2025. This would result in lower gasoline prices (10 cents per gallon) and diesel prices (one cent per gallon) and higher refinery margins in 2025 than in the Base Case.[19] In the cost-benefit analysis, staff applied a one-cent lower gasoline price, growing by one-cent annually, to five-cents per gallon from 2021-2025 attributed to LDD's gasoline displacement. This resulted in $822 – $80 million savings assuming a 5 and 12 percent discount rate, respectively. These results were combined with the Consumer's Direct Non-Environmental Benefits.

An additional benefit, not valued in the analysis, is that expanded use of LDDs opens the diesel market to using significantly greater amounts of gas-to-liquids and renewable diesel fuels. Without this balancing effect, significant use of these alternative diesel fuels and renewable fuels would be counterproductive to market demand and would be significantly market-limited.

## Results

Tables 2 and 3 display the results for reduced gasoline and increased diesel fuel use from LDD vehicles, using the "Futures Model," an Energy Commission model employed to determine the change in gasoline and diesel volumes and Cost-Benefits of the various options. The results are expressed assuming a 5-12 percent discount.

### Table 2. Petroleum Reduction and Benefits for Light-Duty Diesel Vehicles

| Efficiency Option or Scenario | Displacement in 2025, billion gallon gasoline equivalent | Reduction from Base Case Demand, percent | Highest Cumulative Benefit or Change, Present Value, 2005-2025, 5% discount rate, Billion $2005 | | | | |
|---|---|---|---|---|---|---|---|
| | | | A | B | C | D | A+B+C+D |
| | | | Direct Non-Environmental Benefit | Change in Government Revenue | Direct Environmental Net Benefit | External Cost of Petroleum Dependency | Direct Net Benefit |
| Low Fuel Price ($1.88 / gal diesel) | 3.4 (1.9) | 15 (8) | 1.0 | (3.5) | 2.4 | 1.5 | 1.4 |
| High Fuel Price ($2.20 / gal diesel) | 2.7 (1.5) | 12 (7) | 1.3 | (2.3) | 1.7 | 1.0 | 1.7 |
| Highest Fuel Price ($2.43 / gal diesel) | 2.5 (1.3) | 11 (6) | 1.3 | (1.7) | 1.4 | 0.9 | 1.9 |
| Includes the EIA-determined reduced gasoline retail prices effect. | | | | | | | |

## Table 3. Petroleum Reduction and Benefits for Light-Duty Vehicles

| Efficiency Option or Scenario | Displacement in 2025, billion gallon gasoline equivalent | Reduction from Base Case Demand, percent | Highest Cumulative Benefit or Change, Present Value, 2005-2025, 12% discount rate, Billion $2005 | | | | |
|---|---|---|---|---|---|---|---|
| | | | A | B | C | D | A+B+C+D |
| | | | Direct Non-Environmental Benefit | Change in Government Revenue | Direct Environmental Net Benefit | External Cost of Petroleum Dependency | Direct Net Benefit |
| Low Fuel Price ($1.88 / gal diesel) | 3.4 (1.9) | 15 (8) | 0.2 | (1.7) | 1.1 | 0.8 | 0.4 |
| High Fuel Price ($2.20 / gal diesel) | 2.7 (1.5) | 12 (7) | 0.4 | (1.0) | 0.8 | 0.5 | 0.7 |
| Highest Fuel Price ($2.43 / gal diesel) | 2.5 (1.3) | 11 (6) | 0.4 | (0.7) | 0.6 | 0.4 | 0.7 |
| Includes the EIA-determined reduced gasoline retail prices effect. | | | | | | | |

# Key Uncertainties

The key uncertainties in this analysis include:

- California consumer response to LDD vehicles under 8,500 pounds (gross vehicle weight). Will LDD vehicle attributes be sufficient to persuade consumers to pay significantly more for them?

- Future higher-efficiency gasoline vehicles significantly offset diesel's operating cost advantage and reduce its attractiveness.

- Will the $NO_x$-stringent, gasoline-based emission regulations make compliant LDD vehicles unattractive to the consumer? Will $NO_x$ standards preclude vehicle manufacturers from offering LDDs in California? Or restrict LDD availability to only the largest of vehicles, where economics and other attributes justify the higher cost?

- Will Corporate Average Fuel Economy (CAFE) regulations be raised to a level that makes diesel engines a more attractive technology for vehicle manufacturers to more significantly deploy in their product offerings?

- Will amendments be necessary, and allowed, by regulators for higher diesel $NO_x$ standards if industry determines the federal Bin 5 levels is market prohibitive? Can modified performance standards for LDDs be developed to maintain equivalent environmental performance as a gasoline equivalent vehicle?

- Will aggressive $NO_x$ reduction regulations be maintained due to evidence that $NO_x$ emission reductions increase ozone formation in volatile organic compound (VOC) limited Air Basins? (see Weekend/Weekday Research) [20]

# Endnotes

[1] *Forecast of California Transportation Energy Demand 2005-2025*. California Energy Commission CEC 600-2005-008.

[2] Bradford Werner & Alex Ricciuti, *Filter Shortage cuts Peugeot-Citroen output,* cited value referenced to ACEA, The European Car Manufacturers Association, Automotive News, 2005.

[3] Future Potential of Hybrid and Diesel Powertrains in the U.S. Light-Duty Vehicle Market, David L. Green, August 20, 2004.

[4] 2003 Integrated Energy Policy Report Subsidiary Volume, *Transportation Fuels, Technologies and Infrastructure Assessment Report*, Pg. 9. http://www.energy.ca.gov/reports/100-03-013F.PDF

[5] Energy Commission staff 2002 and 2004 conversations with refinery industry knowledgeable people and Energy Commission staff (Mr. Ramish Ganeriwal, Energy Commission staff, Mr. Anthony Finizza, AJF Consulting).

[6] CARB Resolution on Diesel Toxicity 1998.

[7] Margo Oge, Director of the EPA's Office of Air & Radiation, as quoted in InsideFuelsAndVehicles.com (October 1, 2002).

[8] Jeff Holmstead, EPA Assistant Administrator's comments made at a Blue Ribbon panel discussion at SAE Annual World Congress, March 2003. Source: Diesel Fuel News, *Top EPA Deputy Nixes any Plan to Trade 'CAFE' for TIER 2 Emissions*, pg.10.

[9] Margo Oge, Director of the EPA's Office of Air & Radiation, as quoted in InsideFuelsAndVehicles.com (October 1, 2002).

[10] EPA Tier 2 Light-Duty Diesel Progress Report, SAE 2004-01-1791.

[11] In 2002, Ford demonstrated ULEV emission levels using a selective catalytic reduction (SCR) aftertreatment on a diesel vehicle. By the end of 2004, Ford announced the development of their Diesel Hybrid Concept Vehicle, the world's first diesel-powered partial zero-emission vehicle. The Concept Vehicle was a research exercise to test how far emissions could be reduced without regard to production viability and costs.

[12] The California Energy Commission, *Analysis of the Department of Motor Vehicles 2003 Vehicle Registrations.*

[13] Oak Ridge National Laboratory, *Future Potential of Hybrid and Diesel Powertrains in The U.S. Light-Duty Vehicle Market*, August 20, 2004.

[14] *Forecast of California Transportation Energy Demand 2005-2025* California Energy Commission CEC 600-2005-008.

[15] David L. Green, Future Potential of Hybrid and Diesel Powertrains in the U.S. Light-Duty Vehicle Market, ORNL, August 20, 2004.

[16] CEC used a proprietary contractor survey data on about 75 percent of all California retail service stations in 1998-1999 and found that about 24 percent of these sites dispensed diesel fuel. These sites were concentrated in cities and urban counties. Thus, the existing accessibility of diesel fuel is not assumed to limit the market growth for diesel vehicles.

[17] 2002 and 2004 conversations with refinery industry knowledgeable people and Energy Commission staff (Mr. Ramish Ganeriwal, Energy Commission staff, Mr. Anthony Finizza, AJF Consulting).

[18] Service Report, *The Impacts of Increased Diesel Penetration in the Transportation Sector*, Office of Integrated Analysis and Forecasting, Energy Information Administration, U.S. Department of Energy, August 1998.

[19] A 30 percent light-duty diesel penetration would reduce gasoline 21.7 percent, increase diesel demand 51.8 percent. Service Report, *The Increased Diesel Penetration in the Transportation Sector*, Office of Integrated Analysis and Forecasting, Energy Information Administration, U.S. Department of Energy, August 1998. http://www.eia.doe.gov/oiaf/servicerpt/intro.html

[20] See http://www.arb.ca.gov/aqd/weekendeffect/weekendeffect.htm and the Journal of the Air & Waste Management Journal, July 2003. http://www.awma.org/journal/past-issue.asp?month=7&year=2003